ATTENTIONAL BOOSTING EFFECT IN PERCEIVED TRUSTWORTHINESS

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ABSTRACT

This thesis sought to explore whether attention could influence trustworthiness evaluation of faces in a cardiac-gated manner. *The attentional boosting effect* describes a facilitated processing of visual stimuli that are presented concurrently with target stimuli. Furthermore, fearful faces presented during the systolic phase of the cardiac cycle are detected more easily and rated as more intense relative to those presented during the diastolic phase. There has been little work regarding the influence of attention (i.e. attending or ignoring a stimuli) on emotional valence embedded within the context of cardiac timing. This study examined how attention may modulate trustworthiness in face evaluation and whether this effect differs depending on the natural phasic pattern of the cardiac cycle. Participants performed a letter detection task, in which computer-generated face stimuli varying on three trust levels (low, neutral, high) obtained from the Social Perception Lab at Princeton University[1] were concurrently presented with a target or distractor letter. The face-letter paired stimuli were time-locked to coincide with the systolic or diastolic phase of the participant's individual heartbeat, followed by a subjective rating task of the preceding face.

Results showed that while cardiac timing did not seem to influence subjective rating, faces that were paired with target letters were overall rated as more trustworthy than faces paired with distractor letters. This effect was significantly greater in neutral relative to low-trust faces, suggesting that simultaneously attending to an unrelated target letter added, rather than enhanced, positive valence to an intrinsically neutral face.

A follow-up study was then conducted to determine whether the attentional manipulation was affecting perceptual salience rather than facial trustworthiness. The study used faces from the

same database as the aforementioned experiment, again time-locked to systolic and diastolic phases. A short-term memory task was added to follow the target detection task, in which participants assessed whether a second face that was presented was the same or different from the immediately preceding face. Results indicated that neither attention nor cardiac cycle significantly affected participants' performance in the short-term memory task. Our studies provide initial support for an attentional boosting effect in trustworthiness of faces, whereby attending to an unrelated target could generate positive valence that is not inherently present in a background face.

BIOGRAPHICAL SKETCH

Michelle Chiu was born in Buenos Aires, Argentina. After completing high school at Brooks School in North Andover, Massachusetts in 2009, Michelle entered The Johns Hopkins University in Baltimore, Maryland. She received a Bachelor of Arts with a major in Neuroscience and a minor in Psychology in May 2014. During the following year, she was employed as a research assistant in the Psychological and Brain Sciences department at The Johns Hopkins University. In August 2015, she entered the Graduate School of Cornell University in Ithaca, New York.

I dedicate this thesis to Mom and Dad for their infinite love and patience.

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INTRODUCTION

Attentional mechanisms and emotion. The coordinated integration of cognitive and emotional processes is crucial to effectively navigating any given environment. As social creatures residing in a world characterized by infinite pieces of information, the close interplay of emotion and attention allows for proper allocation of limited mental resources under various contexts and guides adaptive behavior. There is substantial evidence indicating that the emotional saliency of stimuli directs selective attention in a bottom-up manner—for example, angry faces (i.e. emotionally salient) tend to attract and hold attention more so than neutral or novel faces[2]. In visual search tasks, subjects tend to require less time to find targets that are emotionally meaningful (e.g. violent scenes, fearful faces) than neutral, and correspondingly, subjects require more time for finding neutral targets in the presence of emotionally meaningful distractors[3]. In addition, emotional salience has been found to be associated with enhanced perceptual vividness, coinciding with the idea that highly emotional stimuli more readily capture attention[4]. From an evolutionary perspective, it seems intuitive that social creatures such as humans would bias attention in favor of emotionally rich stimuli; the angry expression on a person's face could signal impending threat and that the person should be avoided. However, to our knowledge, there has been less work showing that this interaction runs along a two-way street; that is, whether increasing one's attention toward an otherwise neutral stimuli could increase its emotional valence. Subsequently, we will be referring to emotional valence as it has been commonly described, embedded within a two-dimensional space model of emotion—emotional valence can span varying degrees of positive or negative, while arousal indicates the intensity that is tied to that emotional state[5,6].

A rising number of studies have suggested that the act of ignoring certain stimuli (i.e. distractors) decreases their emotional value relative to that of previously attended stimuli, or targets—this effect has been coined the *distractor devaluation effect* [7-10]. The distractor devaluation effect is proposed to arise from the connection established between top-down inhibition (response or attentional) and distractor stimuli, which is then stored and as a result, these stimuli are later recalled and judged to be more negatively affective[8-10]. It has also been shown that the degree of distractor devaluation can vary in a spatial manner, such that the closer a distractor is to the target, the more negatively it is rated, and the opposite is true with increasing distance[10]. Results from a study by Nobre et al. (2012) showed that top-down motor control seems to modulate affective responses by influencing brain regions responsible for encoding the value of stimuli, whereby faces associated with top-down inhibition of a motor response were subsequently rated more negatively, or less trustworthy, than faces not linked to top-down inhibition[11]. Taken together, these studies suggest that decreasing attention, or engaging top-down inhibition, can negatively influence the value of certain stimuli.

A question that follows naturally is whether increasing attention can lead to opposite results. Target detection has been shown to interfere with and impair the processing of other information presented at the same time or shortly preceding and following the target, which has been interpreted as a cost incurred due to limited attentional resources[12,13]. However, there is evidence to suggest that target detection can also enhance performance in a second task; for example, subjects seem to remember color arrays[14] and background scenes[15] that were presented simultaneously with unrelated targets better than those that were presented with distractors. Dubbed *the attentional boost effect*[16], it explains how these results could be because the appearance of a target stimuli represents a task-relevant change that then necessitates and recruits additional attentional resources in a temporally constrained manner[15,17,18]. Notably, this effect is not influenced by the perceptual saliency of the occasionally appearing targets[15,16,18]. Following a similar line of thought, Schonberg et al. (2013) used cue-approach training to manipulate the intrinsic value of a food item—a group of palatable food items were first separated into low or high-value items according to how much the participant was willing to pay for them. Following cue-approach training, participants were shown low-value or high-value item pairs and asked to choose one of the two in each trial. Results showed a significant increase in choice for items that were previously associated with a tone cue compared to items that were not associated with a tone cue in the cue-approach training task; assuming that choice behavior can reflect the value of an item, these results suggest that increased attention to these cued items may be related to their increased value[19]. In particular, this increase in choice applied only for high-value item pairs, so these results could be interpreted to mean that increasing attention enhanced the positive valence that was already intrinsically present in the food item.

Mind-body interaction in emotion. As early as the late nineteenth century, it was proposed that physiological changes within the body provide a crucial link between mental perception and emotion such that, without that connection, all experiences would be devoid of emotional context [20,21]. William James went so far as to state that these bodily changes are meshed within one's consciousness: "If we fancy some strong emotion, and then try to abstract from our consciousness of it all the feelings of its characteristic bodily symptoms, we find we have nothing left behind"[21]. More than a century later, the pervasive influence of visceral experience on emotion, cognition, and behavior has become more widely acknowledged. There is increasing evidence supporting a dynamic relationship between bodily states of arousal and our cognition and subjective emotional perception [22-25].

Neuroanatomy of visceral afferent inputs to the brain. Visceral input can be divided into two major pathways, one of which primarily carries motivational information (i.e. getting a glass of water to satisfy thirst) while the other mostly signals tissue damage. Specifically regarding the former channel, motivational information is carried by the vagus and glossopharyngeal cranial nerves to arrive at the NTS (nucleus of the solitary tract), where visceral inputs arising from various organs (heart, stomach, renal) and visceroceptors (baroreceptors, thermoreceptors, chemoreceptors) merge at an early stage across modalities. NTS then projects to the proximal regions of PBN (parabrachial nucleus), PAG (periaqueductal gray), and the thalamus, where viscerosensory signals are integrated into organized autonomic and hormonal output[26,27]. These areas are further anatomically and functionally linked to forebrain regions including the amygdala, anterior cingulate cortex, insular cortex, and orbitomedial prefrontal areas [28,29]. Bodily signals are therefore continuously relayed to cortical and subcortical regions, such that fluctuations on either end would shape and exert influence on the other. Despite evidence supporting the influence of peripheral physiological states on mental processes[22-25,28,30,31], their exact relationship remains unclear, especially pertaining to emotion.

Cardiac timing and stimuli processing. Before diving into the evidence linking physiological arousal and emotion, it is helpful to understand why cardiac cycle is useful as a marker for autonomic arousal[22]. The cardiac cycle is a natural oscillating pattern between systole and diastole phases, which translates into the timing and strength of individual heartbeats. At each heartbeat, or ventricular systole, blood is ejected from the heart into the aorta and carotids, activating stretch-sensitive mechanoreceptors (baroreceptors) that are located within the aortic arch and the carotid sinus. These phasic bursts are transmitted by the vagus and glossopharyngeal nerve afferents to the brainstem, where signal information is processed to enable adaptive regulation of blood pressure [32], dubbed as the baroreceptor reflex. Following each contraction is a recovery phase, or diastole, when the ventricles are relaxed and the baroreceptors are silent. These afferent inputs extend past the brainstem and into forebrain regions. Thus, the relationship between cardiovascular arousal and mental and perceptual processing can and has been studied by comparing responses to brief stimuli presented at systole versus diastole, either in the natural or perturbed state of cardiac phase. Studies using cardiac timing have implicated brain regions such as the anterior cingulate, amygdala, insula, and brainstem nuclei that represent states of bodily arousal as well as modulate attentional and emotional processes[23-25,33,34]. Initial evidence suggested a blunting or suppression in processing of stimuli concurrently presented with baroreceptor firing at systole, more specifically an attenuation of subjective pain perception and pain-evoked potentials for shocks presented in conjunction with baroreceptor activation [35-37]. A follow-up study using electroencephalography found that the magnitude of a later component of pain-evoked potential (400 ms after shock delivery) differed between expected and unexpected shock stimuli delivered at diastole but not for stimuli delivered at systole[33]. These results indicate that the modulatory effect of attention on pain processing could be gated by cardiac baroreceptor signaling and that this effect manifests itself at a later stage of sensory representation[22]. A magnetoencephalographic study found that stronger neural responses in the ventral anterior cingulate cortex and ventromedial prefrontal cortex linked to heartbeat increased the likelihood for conscious detection of faint visual stimuli, but there was no indication that cardiac timing directly affected detection of stimuli[38]. Since this study used grating annulus as its stimuli, it does not show whether cardiac timing would similarly have no direct influence on the detection of affect-laden stimuli such as emotional facial expressions. A study conducted by Garfinkel et al. (2014) revealed an improved detection and enhanced subjective perception of intensity for fearful faces presented at systole compared to diastole, an effect that was linked to bilateral engagement of the amygdala; notably, they found no significant difference for disgust, happy, or neutral faces[24]. Fearful face stimuli notably engage neural mechanisms that process and represent potential threat-related signals in the environment[39] and there is robust evidence indicating that rapid detection of fearful facial expressions poses a clear evolutionary advantage; studies have found that enhanced attention for fearful expressions emerges in children[40,41] as young as 5 months of age[42], concurring with evidence in adult subjects for a facilitated detection for fearful faces[43] and enhanced neural responses for fearful faces in the visual cortex[40,44]. Understandably, it is highly beneficial for humans to efficiently detect dangerous situations, but this process must also be actively controlled and integrate contextually specific cues to allow for flexible and adaptive responses.

According to the fear generalization hypothesis, the likelihood of a fear response is linked to the perceptual similarity of an encountered situation and one that was previously learned to be threatening. However, Onat and Buchel found neural evidence for a higher level of threat processing, which involves a more specific encoding of threat combining threat identification with ambiguity-based uncertainty[45]. If this level of specificity is apparent in an emotion like fear that is closely connected to visceral response and physiological arousal[39], we could imagine the same being true for other forms of emotive stimuli. Also, the cardiac-gated modulatory effect of attention demonstrated using shock stimuli might manifest differently in other types of affective stimuli. That baroreceptor stimulation inhibits and enhances stimuli processing fits in with the idea of a highly specific level of processing that engages parallel streams of information, thereby allowing adaptive behaviors that are contextually specific but also quickly executed. Although prior evidence highlights a cardiac-gated enhancing effect specific to detecting the presence of threat or affectively negative stimuli (i.e. fearful faces), it was noted previously that visceral input is richly integrated across modalities to allow for equally complex patterned neural and behavioral responses, consequently the same channel that conveys information leading to approach behavior (i.e. pleasant taste) can also carry signals that inform avoidance behavior (i.e. presence of threat)[28].

Emotional expressions and trustworthiness. Studies have shown that emotional facial expressions are strongly associated with trait judgments (e.g. an angry face is judged to be more dominant), so much so that even when subjects were asked to evaluate neutral faces, their trait and emotion ratings remained strongly correlated[46,47]. The emotion overgeneralization hypothesis[48,49] states that a person's trait attributes and behavioral inclinations can be derived from the perceived similarity between neutral faces and emotional expressions. Todorov et al. (2008) demonstrated that face evaluation can be characterized along two social dimensions: valence and dominance evaluation[1]. Among thirteen trait judgments of both natural and computer-generated faces, trustworthiness featured as the trait that was most highly correlated with valence evaluation of faces[1]. Furthermore, there appears to be a shared basis of perceptions of face trustworthiness and expressions of anger and happiness[50], meaning that untrustworthy faces with angry expressions were perceived to be more angry than trustworthy faces with the same emotion. Just as studies have shown a facilitated detection for fearful facial expressions[41,42,51], there seems to also be preferential attention allocation for faces expressing anger[2]. One interpretation could be that both fearful and angry expressions signal potential threat in the environment, such that a lowered detection threshold for either is evolutionarily advantageous. Given that trustworthiness seems closely associated with emotional expression in face perception and that cardiac gating influences attention-modulated perception of emotive stimuli (i.e. shocks), it is possible that trustworthiness judgments could be similarly regulated by cardiac timing and attention. To our knowledge, there have been no studies investigating the effects of cardiac timing and attention on trait judgments.

EXPERIMENT 1A: CARDIAC TIMING AND ATTENTIONAL BOOSTING IN TRUSTWORTHINESS EVALUATION

STUDY OBJECTIVES

Our study sought to elucidate the potential influence of cardiac timing on the attentional boost effect in trustworthiness of faces. Assuming that top-down attentional mechanisms and cardiac timing influence stimuli processing, we hypothesized that there would be an enhancement effect on neutral and positively valenced face stimuli that is further regulated by attention and cardiac cycle. Similar to the increased choice behavior for high-value item pairs found in the study conducted by Schonberg et al. (2013)[19], we predict that positive valence will be enhanced for neutral and high trust level faces, such that face stimuli paired with target letters will be rated as more trustworthy relative to those paired with distractor letters. We suspect that this enhancement will be further modulated by cardiac timing, meaning that the effect of attention on differences in trustworthiness rating will be even greater for face stimuli presented at systole than at diastole.

Participants performed two consecutive tasks in each trial: a target detection task and a trustworthiness/ confidence-rating task. For the target detection task, participants pressed a space bar whenever an occasional target letter appeared (T:D ratio was 1:1). Each participant was randomly assigned a letter as target throughout the entire duration of the task. Immediately after each detection task, participants provided trustworthiness ratings and confidence ratings for the preceding face.

MATERIALS AND METHODS

Participants. 32 participants (22 female, 10 male) were recruited among students at Cornell University. Three participants were excluded due to error in heart rate recording. All participants reported normal or corrected-to-normal vision and gave written informed consent prior to participation. All received course credit in exchange for their participation. One participant was excluded from data analysis due to poor letter detection task performance.

Stimuli. Stimuli consisted of 84 Caucasian faces randomly generated using FaceGen 3.1, obtained from the Social Perception Lab at Princeton University[1,50]. Each facial identity had 3 versions that varied on trustworthiness (-3, 0, 3 SD) based on the trustworthiness computer model generated by Oosterhof & Todorov[1]. 4 distinct faces (each with 3 trustworthiness levels) were used in the practice trial. The remaining 80 distinct faces were used in the experimental task, totaling 240 faces (80 faces with 3 trustworthiness levels each).

Experimental design. The experiment consisted of 240 trials divided into four blocks of 60 trials, where each trial within every block consisted of a target detection task immediately followed by an evaluation task. Between each experimental block, the participant was given the option of a self-timed break. Trials were randomly and evenly divided according to letter condition (target or distractor) and trust levels (low, neutral, high) in each block. Using methodologies adapted from previous cardiac timing experiments[24,25], stimuli were evenly and randomly distributed to be time locked at either systole (R-wave) or diastole (T-wave). Participants were randomly assigned a target letter from a pool of five letters (X, H, T, L, or V), with the remaining four being distractors.

Target detection task. In the letter detection task, each participant was first presented with a fixation cross against a black background for 800 ms, followed by one face at the center of the screen lasting for 100 ms. A target or a distractor letter would be presented concurrently with the face, with the individual letter overlapping the nose of the face. Participants were instructed to press a space bar as quickly and accurately as they could only if the letter was a target letter. There was a 1500 ms response window following the face-letter stimuli presentation, regardless of whether the participant pressed a button or not (Figure 1).

Trustworthiness and confidence rating. The rating task consisted of two self-timed screens that appeared one after the other, both consisting of the same discrete rating scale. Corresponding to each screen, participants were required to rate the immediate preceding face (from the letter detection task) on its trustworthiness and their confidence in the trustworthiness rating. Both ratings were given on a 9-point scale ranging from 1 (‘very untrustworthy’, ‘very unconfident’) to 9 (‘very trustworthy’, ‘very confident’). Participants were provided with written instructions and a practice session consisting of 12 trials prior to beginning the experimental task. The target letter assigned in the practice session remained the same for the entire duration of the experimental task.

Heart phase recording. Electrocardiography (ECG) was acquired while participants sat in a chair, enabling assessment of heart peaks. Using the BioPac MP150, ECG signal was measured and transmitted at a rate of 2000 Hz via the Dual RSP/ECG BioNomadix amplifier system. Real-time detection of physiological heart peaks was achieved on a Windows computer through a scripted program in Python[52], enabling the presentation of stimuli to be time-locked at systole or diastole, with diastole set at 300 ms following each detected peak (systole) in each cardiac cycle.

Five total trials (pooled across all trials) were excluded from data analysis due to synchronization failure between stimuli presentation and heart peak detection.

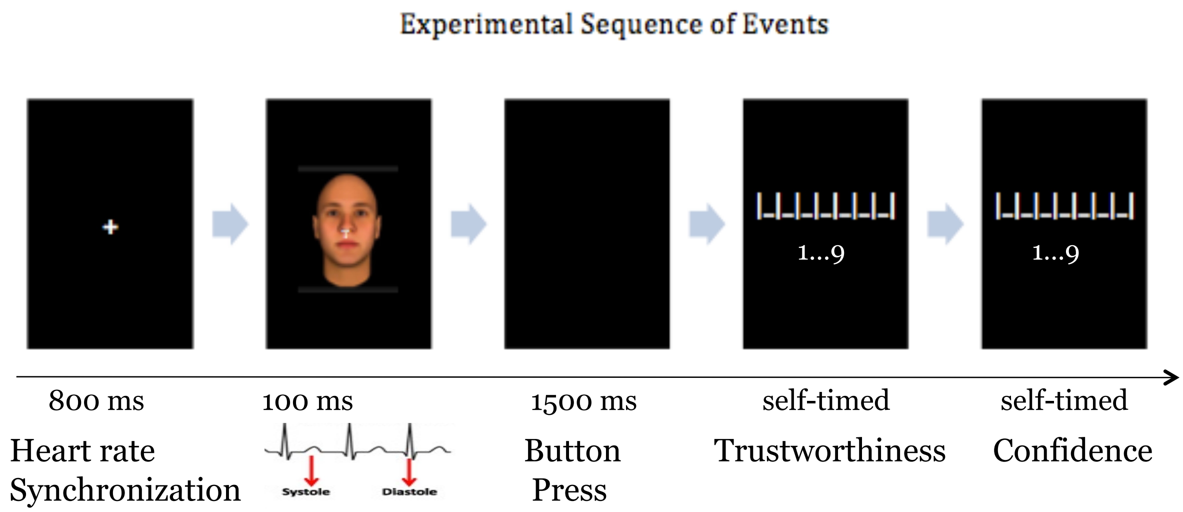


Figure 1 | Experimental task and stimuli timing. Participants completed a target detection task where brief computer-generated faces were presented to coincide with systole and diastole phases of their cardiac cycle, followed by a trustworthiness and confidence-rating task. Each rating scale featured “very untrustworthy” or “very unconfident” below the lowest numeric value and “very trustworthy” or “very confident” below the highest numeric value.

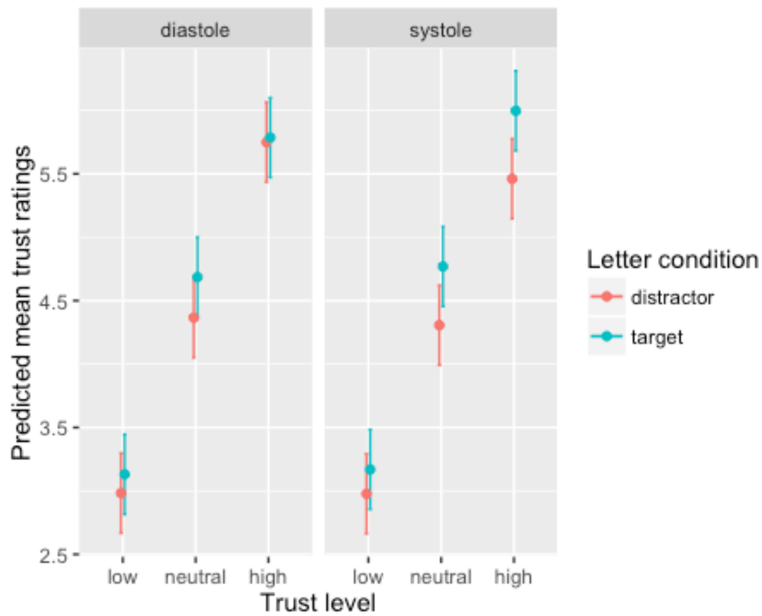
STATISTICAL MODELING

The influence of trust level, cardiac timing, and attention (target/distractor letter) on trustworthiness ratings was assessed using LS-means (least squares means) derived from a hierarchical linear mixed-effects regression model that used the lmerTest package in R[53]. LMER enables control of variance associated with random factors[54,55]. By using random effects for subjects (n=31) and distinct face stimuli (n=80), we adjusted for the influence of different mean trustworthiness ratings associated with these variables. As fixed effects, we entered trust level, cardiac timing, and attention (with interaction terms) into the model. We report only the estimates of the LS-means, because although LS-means and centered variables yield the same estimates, LS-means allowed us to conduct joint tests of main effects without the use of nested models (as would be the case with LMER). Additionally, centering variables presents slightly biased standard errors. Given that, the values we report are actually chi-squared values—as the degrees of freedom approaches infinity, which is the case with our model that encompassed more than 3000 observations, the p-values obtained from an F-distribution approach the p-values of a chi-squared distribution.

RESULTS

There was a significant main effect of trust (chi [2] = 2497.1, $p < .0001$) on trustworthiness ratings, meaning trustworthiness ratings progressively increased between trust levels, such that low-trust face stimuli were rated least trustworthy, high-trust face stimuli were rated most trustworthy, and neutral-trust face stimuli fell in between. There was also a significant main effect of attention (chi2 [1]=11.957, $p=0.0005$) on trustworthiness ratings, in which faces presented with target letters were overall rated as more trustworthy than those presented with distractor letters. Cardiac cycle did not have a significant main effect on trustworthiness ratings (chi^2 [1] = 0.002, $p=0.966$), so collapsing across trust levels and letter conditions, faces shown at diastole were rated as equally trustworthy relative to those shown at systole (Figure 2A). There was a significant two-way interaction (Figure 3) between neutral and low-trust levels across letter conditions (chi^2 = 0.22, SE=0.077, $p=0.004$), where there was a significantly greater difference in rating between faces paired with target or distractor letters for neutral-trust faces compared to low-trust faces. We did not observe a significant two-way interaction between attention and cardiac phases (chi^2 = 0.23, SE=0.163, $p=0.157$). However, there was a significant three-way interaction between trust, cardiac cycle and attention (chi^2 [2] = 4.876, $p= 0.008$) particularly when contrasting high and low-trust faces.

A



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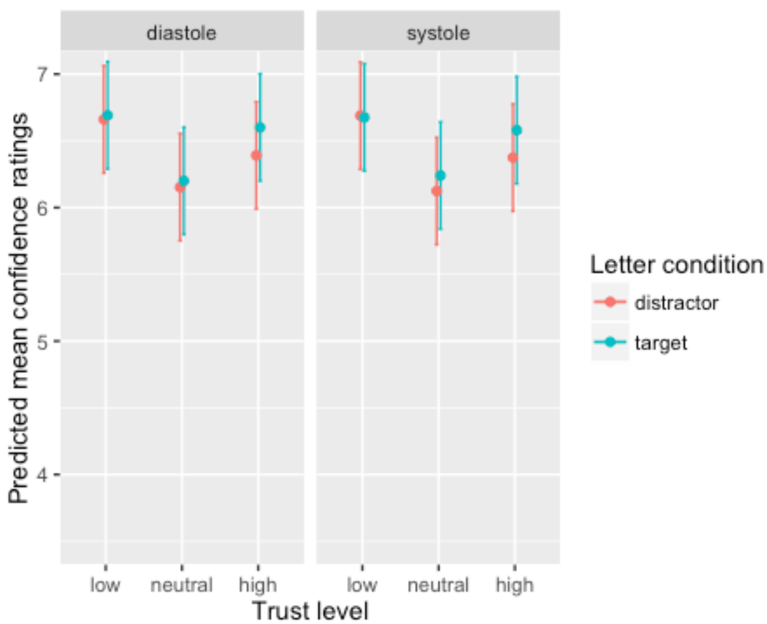

Figure 2 | Ratings for perceived trustworthiness and confidence of face stimuli. (A) Model-based means for trustworthiness ratings, displaying a significant main effect of trust ($p<0.0001$) and letter condition ($p=0.0003$) and a significant two-way interaction between letter condition and trust level, specifically between neutral and low trust level faces ($p=0.004$), and a three-way interaction ($p=0.07$) between high and low trust level faces. **(B)** Model-based means for confidence ratings revealed that confidence ratings did not exhibit the same pattern as trustworthiness ratings across trust and letter conditions.

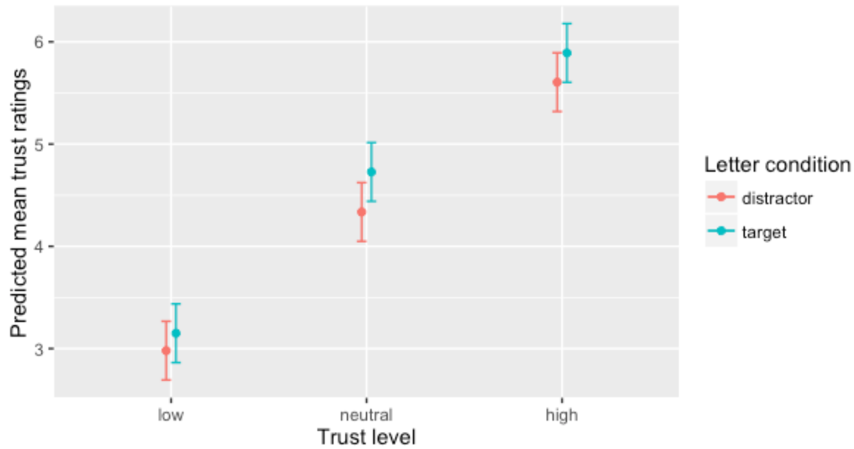

Figure 3 | Effect of attention on trustworthiness ratings averaged over heart phases. There is a significant two-way interaction (p=0.004), where the difference in trustworthiness rating between target and distractor letter conditions is greater for neutral-trust faces than low-trust faces.

EXPERIMENT 1B: THE EFFECT OF ATTENTION ON SHORT-TERM MEMORY PERFORMANCE

STUDY OBJECTIVES

In order to explore whether attention is modulating perceptual detection rather than trustworthiness, or valence, we conducted a second experiment that was similar to Experiment 1 but also incorporated a short-term memory task. If attention were influencing perceptual detection rather than valence, we would expect to see better performance overall on the short-term memory task for face stimuli presented with target compared to distractor letters. Similar to Experiment 1, face stimuli were time-locked to cardiac phase and participants were asked to evaluate faces on trustworthiness and trustworthiness; these data will be presented in a future report. The following results focus on elucidating whether attentional manipulations influence the perceptual salience rather than intrinsic valence or trustworthiness of a face.

MATERIALS AND METHODS

Participants. 27 participants (18 female, 5 male) were recruited among students at Cornell University. Four participants were excluded from data analysis due to poor letter detection task performance (< 90% accuracy). All participants reported normal or corrected-to-normal vision and gave written informed consent prior to participation. All received course credit in exchange for their participation.

Experimental design. The experiment was similar to Experiment 1 (target to distractor ratio was 1:1) except that the target detection task was followed by a short-term memory task instead of a trustworthiness and confidence-rating task.

Stimuli. Stimuli consisted of 100 computer-generated Caucasian faces that varied along the same trustworthiness levels (low, neutral, high) as Experiment 1, obtained from the Social Perception Lab at Princeton University[1,50]. 4 distinct faces of neutral trust level were used in the practice trials. The remaining 96 distinct faces were used in the experimental task, so excluding the faces from the practice trials, 288 faces (every face had 3 levels of trust) were presented to each participant.

Experimental task: overview. The experiment consisted of 192 trials divided into four blocks of 48 trials, where each trial within every block consisted of a target detection task immediately followed by a short-term memory task. Between each experimental block, the participant was given the option of a self-timed break. Trials were randomly and evenly divided according to letter condition (target or distractor), trust levels (low, neutral, or high), and face condition (same or different) in each block. Using methodologies established in previous cardiac timing experiments[24,25], stimuli were evenly and randomly distributed to be time locked at either systole

(R-wave) or diastole (T-wave), with diastole set as 300 ms following a detected peak of each cardiac cycle. Participants were randomly assigned a target letter from a pool of five letters (X, H, T, L, or V), with the remaining four being distractors.

Target detection task. The letter detection task was identical to Experiment 1 (Figure 4).

Short-term memory task. Immediately after each letter detection task, a second face would be briefly presented for 100 ms, followed by a self-timed response window during which the participant presses either "s" or "d" on the keyboard depending on whether the second face was the same or different from the first face, respectively. The first face (that was paired with a letter) and the second face were randomly and evenly paired but restricted in that both faces belonged to the same trust level (e.g. in any given trial, participants would never be exposed to a high-trust face for the letter detection task and then a low-trust face for the memory task). Participants were provided with written instructions and a practice session consisting of 12 trials prior to beginning the experimental task.

Heart phase recording. Face stimuli were time-locked according to real-time detection of physiological peaks in each cardiac cycle[52], identical to methods in Experiment 1.

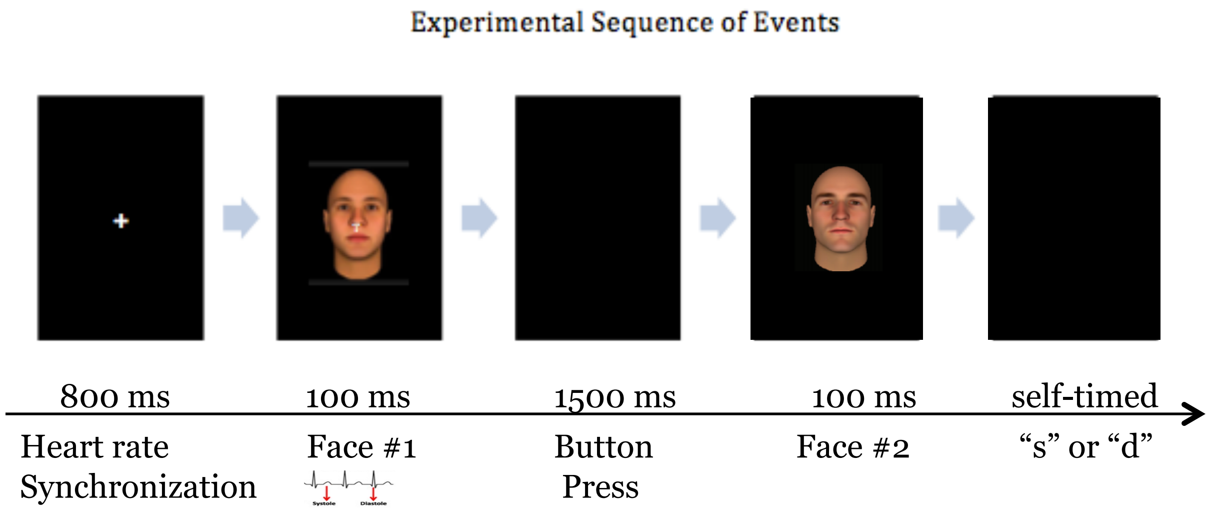

Figure 4 | Experimental task and stimuli timing for Experiment 2. Participants completed a target detection task where brief computer-generated faces were presented to coincide with systole and diastole phases of their cardiac cycle, followed by a short-term memory task.

RESULTS

Overall, participants did not perform as well on the short-term memory task (mean accuracy = 70.95 %, SD= 4.54 %) as they did on the target detection task (mean accuracy=96.98%, SD= 1.71%). We did not find a main effect of trust (ch^2[2]=1.984, p=0.137) or attention (ch^2[1] =0.02, p=0.887) on short-term memory performance (Figure 5), suggesting that the trustworthiness of the face and whether it was paired with a distractor or target letter did not seem to influence how well the faces were remembered.

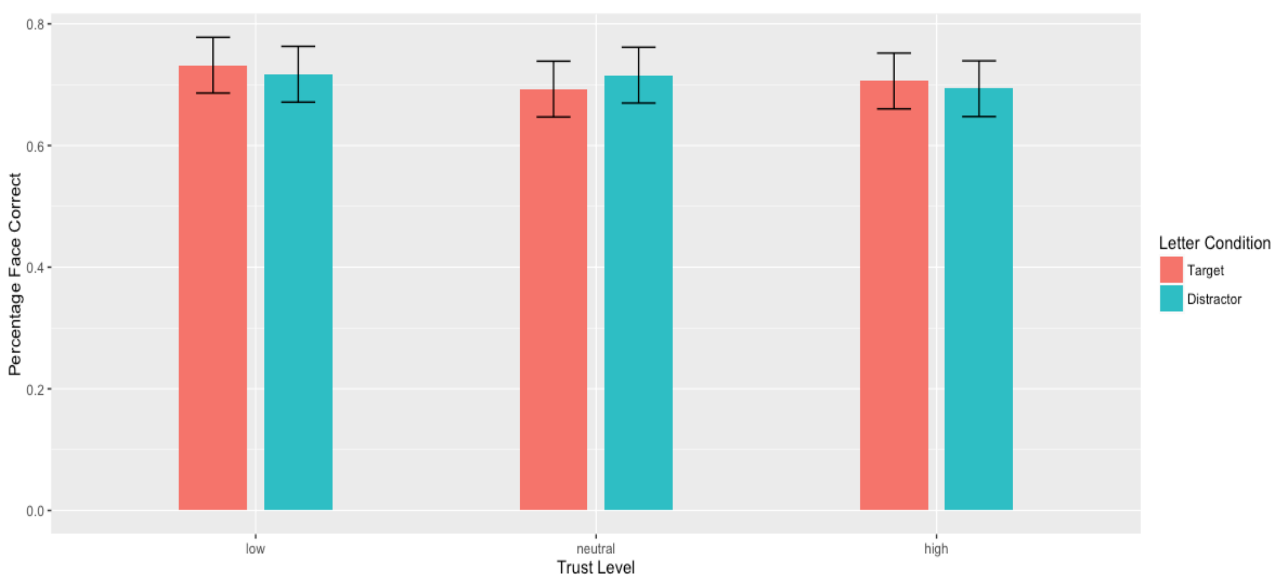

Figure 5. Performance on short-term memory task collapsed across heart phases. Letter condition or trust levels did not significantly affect participants' performance in the short-term memory task.

DISCUSSION

In *the attentional boosting effect,* there is enhanced memory for images (e.g. scenes, faces) presented simultaneously with unrelated targets compared to those presented at the same time as distractors[15,18]. This 'boosting', moreover, does not seem to originate from an increase in arousal, motivation, or task engagement[14,16]. Schonberg et al. (2014) extended this effect to choice behavior by using a cue-approach training task and showed that participants preferentially chose high-value food items that were paired with a tone cue over those that were not paired with a tone cue, which suggests that the act of attending could also increase the value of an item. There has also been evidence that cardiac timing could play a role in an attention-dependent manner; specifically, fearful faces have been found to be more easily detected and perceived as more intense when presented during the systolic rather than the diastolic phase of the cardiac cycle[24]. In so much as food item values parallels with perceived valence in faces, we wanted to investigate whether the attentional boosting effect can be observed in trustworthiness evaluation and if cardiac timing would further augment this effect.

In the first part of our study (Experiment 1a) we asked participants to rate faces, which were time-locked to systole or diastole, on a trial-by-trial basis after performing a letter detection task. While cardiac timing did not seem to affect ratings, we did find that faces presented with target letters were rated as more trustworthy than faces presented with distractor letters. Specifically, this difference was greater for faces of neutral trust level when compared to that of low-trust faces. The second part of our study (Experiment 1b) assessed whether the difference in ratings reflected an improved short-term memory. If the differences in trustworthiness ratings of Experiment 1a stemmed primarily from a difference in perceptual salience or detection of these faces (i.e. faces were rated as more trustworthy because they were seen more clearly), then we would expect participants to remember faces that were paired with targets better than faces paired with distractor letters. However, participants performed similarly regardless of trust level or attentional manipulation, which suggests that the results from Experiment 1a point to an effect of attention on intrinsic valence, or trustworthiness.

Presuming that neutral trust level faces are also neutral in emotional valence (i.e. neither positively nor negatively valenced), it remains unclear whether the significant two-way interaction between trust and attention that we found in Experiment 1a stems from a distractor devaluation or an attention boosting effect, since we did not establish a baseline measure of trustworthiness rating. However, there is evidence for this being an attentional boosting effect. In a series of studies conducted by Swallow and Jiang (2011), separate groups of participants were asked to remember faces that either preceded ("image early"), followed ("square early") or were presented at the same time ("overlap") as a target or distractor square. Results revealed that while the 'boosting' effect (i.e. target-paired faces were remembered better than distractor-paired faces) was found in the "overlap" condition, participants' hit rate on the image recognition task was similar between target and distractor-paired faces in the "square early" and "image early" conditions, and this performance was level with that of the distractor-paired faces in the "overlap" condition[18]. Nonetheless, it would be useful to conduct a future study consisting of only neutral-trust faces that precede, follow, or are concurrently presented with targets or distractors, in order to better determine if the difference in rating between letter conditions and the enhanced difference for neutral-trust faces we observed are indeed due to an attentional boosting and not a distractor devaluing.

To the best of our knowledge, these results indicate for the first time how simultaneously attending to an unrelated target could, independent from the fluctuations of cardiac timing, potentially create, instead of simply enhance, positive emotional valence in trustworthiness evaluation of faces, thus providing new insight into the effects of attention on emotion.

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